Hyperloop pod competition

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The **Hyperloop Pod Competition** is an incentive prize competition sponsored by SpaceX that is being held in 2015–2018 where a number of student and non-student teams are participating to design—and for some, build—a subscale prototype transport vehicle to demonstrate technical feasibility of various aspects of the Hyperloop concept. The competitions have been open to participants globally, although all competitions and judging has occurred in the United States.

There were three judging phases in the 2015–2017 competition: a design competition that was held in January 2016, and two on-track competitions. The first was held 27–29 January 2017,[1][2] and the second, Competition Weekend II, was held 25–27 August 2017.[3] The on-track portion of the competition is run on the *SpaceX Hyperloop test track*—or *Hypertube*—a mile-long, partial-vacuum, 1.83-meter (72.0 in)-diameter steel tube purpose-built in Hawthorne, California for the competition.[4]

30 of the 115 teams that submitted designs in January 2016 were selected to build hardware to compete on a sponsored Hyperloop test track in January 2017.[5][6] There were more than 1,000 applicants at earlier stages of the competition.[7] The first competition completed in January 2017. WARR Hyperloop, from the Technical University of Munich won top honors. In April 2017, 24 teams were selected to compete in Competition Weekend II held in August; WARR Hyperloop won top honors with a 323 kilometres per hour (201 mph) top speed in the mile-long test track.[3]

In January 2016, SpaceX announced they would sponsor additional competitions in future years,[8] and have continued that with a third competition planned for summer 2018, in which new student teams may be formed to compete.[9]

Contents

History

The outline of the original Hyperloop concept was made public in August 2013 by the release of a preliminary —or alpha level—design document by Elon Musk, with substantial design assistance from an informal group of engineers at both Tesla Motors and SpaceX who worked on the conceptual foundation and modelling of Hyperloop. The preliminary design called for a 2.3–3.4-meter-diameter (90–132 in) steel tube, operating in partial vacuum (nearly airless), utilizing pressurized vehicle "pods" to carry passengers or cargo that would ride on an air cushion driven by linear induction motors and air compressors.[10] The alpha design included a notional route running from the Los Angeles region to the San Francisco Bay Area, paralleling the Interstate 5 corridor for most of its length, so that preliminary economic analysis might be done on the concept.[11] Responses to the design paper release included: "a flash of brilliance" and "hypercool"[12] to "nothing new here"[10] to "hype", "another science-fiction dream," and "completely impractical."[13]

Within days of the 2013 announcement, discussions concluded that building a successful Hyperloop subscale demonstration project could reduce the political impediments while improving cost estimates; Musk suggested that he could choose to become personally involved in building a demonstration prototype of the Hyperloop concept, including funding the development effort.[14][15]

On 15 June 2015, SpaceX announced that they would sponsor a Hyperloop pod design competition, and would build a 1-mile-long (1.6 km) subscale test track near SpaceX's headquarters in Hawthorne, California, for the competitive event. The competition could be held as early as June 2016.[16][17] SpaceX stated in their announcement, "Neither SpaceX nor Elon Musk is affiliated with any Hyperloop companies. While we are not developing a commercial Hyperloop ourselves, we are interested in helping to accelerate development of a functional Hyperloop prototype."[18] More than 700 teams had submitted preliminary applications by July.[19]

Detailed competition rules were released on 29 August 2015, with revisions in October.[20] Formal *Intent to Compete* submissions were due 15 September 2015 and the detailed tube and technical specification—anticipated to be released by SpaceX in October 2015[21]—became available somewhat later.[4] A preliminary design briefing was held in November 2015,[22] and as of October 2015, *Final Design Packages* were due on 13 January 2016. A *Design Weekend* was held at Texas A&M University on 29–30 January 2016 for all invited entrants. The selected pods will compete at the *SpaceX Hyperloop Test Track* in January 2017.[21]

More than 120 student engineering teams were selected from the preliminary design briefing presentations in November to submit final design packages in January 2016. The designs were released to public view prior to the end of January 2016, and selected teams were invited to build hardware and compete in time trials in mid-2016.[22]

SpaceX announced in January 2016 that they had engaged a Los Angeles-based, Fortune-500, engineering design and construction firm AECOM to build the Hyperloop test track.[23]

At a 29–30 January 2016 meeting at Texas A&M University, hosted by the College of Engineering, the designs from the approximately 120 worldwide teams were reviewed and judged. 30 teams were selected to go forward and build prototype Hyperloop pods for the competition later in the year.[5][6]

On 30 January 2016, Musk announced that, due to the level of sophistication of the pod designs as well as design issues with economical design approaches to building the test track, "given this level of enthusiasm, there is no question we are going to have another Hyperloop competition."[8] Further information came in

August 2016: teams sign-up deadline is 30 September 2016 to compete in the second pod competition sometime in 2017.[24]

TechCrunch published a photograph of the pod competition test track while under construction in September 2016.[25] Competition teams visited the track for fit checks and vacuum/track tests during the first week of November, and a video was released.[2]

The on-track portion of the competition finally got underway on 27 January 2017.[1]. WARR Hyperloop, from the Technical University of Munich won top honors.

In April 2017, 24 teams were selected to compete in *Competition Weekend II*. Held in August 2017, WARR Hyperloop won top honors once again, this time with a 323 kilometres per hour (201 mph) top speed in the mile-long test track.[3]

In September 2017, SpaceX announced that they would sponsor another competition in summer 2018.[9] As with the *Competition Weekend II* in 2017, only student teams may enter the competition, and the "competition will be judged solely on one criteria: maximum speed with successful deceleration (i.e. without crashing)."[26] Unlike the two test track competitions in 2017 however, all pods must be self-propelled. SpaceX will not provide an external pusher-vehicle as they did provide to facilitate student team pod testing in both the January and August 2017 competitions. Ultra-small pods will not be allowed this time, with minimum pod length set at 1.5 metres (5 ft). There will be an additional sub-competition with up to three qualifying teams allowed to take part in a *Levitation Sub-Competition* that will require non-wheeled pod levitation and will be tested on an external (non-vacuum) test track. The pods will need to translate at least 75 feet (23 m) down the track, stop, reverse, and translate back to the original position, all while levitating the entire duration. Fastest full cycle wins the levitation sub-competition.[26]

Technical overview

The 2016 competition will take place on a 1-mile-long (1.6 km), 1.8-meter-diameter (6 ft) test track being built in southern California.[16][23] Test pods may not carry any human or animal, and are to be used solely to develop new technologies and subsystems for effecting higher-velocity tube transport systems.[27] The track will facilitate pod test runs where each pod is accelerated, achieves a top measured speed that is reported in real-time, and then decelerates by braking, ostensibly before the end of the test track. There will be a crash pit after the end of the track to absorb the energy of any test pods that fail to come to a stop in the test track tube.[7][8]

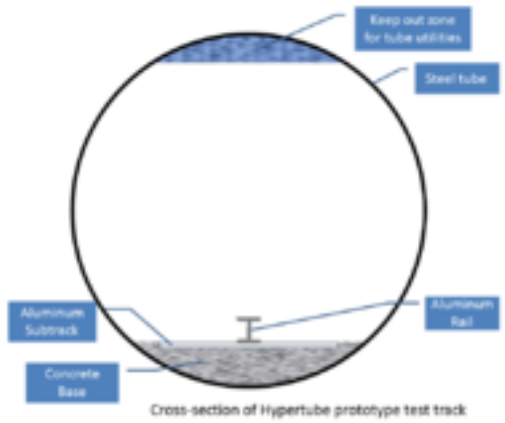
Test track

The **SpaceX Hyperloop test track** — or *Hypertube*[4] — was designed in 2015 and was constructed in 2016, reaching its full length of one mile by October 2016.[28] The test track itself is also a prototype, where SpaceX anticipates learning from the design, build process and evaluates how to apply automated construction techniques to future Hyperloop tracks.[8]

The design of the pod test track varies significantly from the Hyperloop tube design shown in the initial alpha-level Hyperloop design concept document released in 2013.[11] The Hypertube test track is designed to enable competitors who implement a wide array of designs and build pods that will test a variety of subsystem

technologies that are important to new vehicle transport systems. This will include Hyperloop-specific pods—with air-bearing suspension and low-pressure compressor designs—as well as wheeled vehicle and magnetic levitation rail designs that will support a wide array of vehicle technologies to be tested. Some pods are expected to test only particular subsystems rather than a full Hyperloop-capable pod vehicle design; as well, many pods will have no on-pod compressor to prevent the high-speed choked-flow problem, very unlike the Hyperloop alpha design.[4]

Multiple systems will be allowed for propulsion and for levitation/suspension of various team pods. Three explicit suspension types are called out: wheels, air bearings, and magnetic levitation. Pod propulsion may be *On-pod*—as envisioned in the alpha Hyperloop design—or for the Hypertube test track, may use a SpaceX-provided *Pusher* to accelerate pods up to speed in the first 15 percent of track length, or even be unique (team-specific) *Off-pod* propulsion systems that would need to be integrated into the Hypertube for that Pod's specific test run.[4]



Cross section of the *Hypertube* test track under construction for the Hyperloop pod competition in August 2016.

Specifications

The test track specifications as of January 2016 include:[4]

- Outer diameter: 1.83 meters (72.0 in)[4] (vs. approximately 2.3–3.4 m (90–132 in) for the tube in the initial alpha Hyperloop design document)[11]
- Inner diameter: 1.79 meters (70.6 in)
- Wall thickness: 18 millimeters (0.70 in)[4] (vs. 20–25 mm (0.80–1.0 in) for the tube in the initial alpha Hyperloop design)[11]
- Length: 1.6 kilometers (1 mi) (approximate)
- Materials
  - Tube: ASTM A1018 Grade 36 carbon steel
  - Rail: Aluminum 6061-T6
  - Subtrack: AA1370-50[29] Aluminum alloy for electrical applications
  - 1.2 m-wide (48.0 in) Concrete base inside the tube to support wheeled-vehicle pods
- Subtrack thickness: 25 millimeters (1.0 in) for first and last 61 meters (200 ft); 13 millimeters (0.5 in) for remainder of tube
- Internal pressure: 0.14–100 kilopascals (0.02–14.7 psi) (competitors may select tube operating pressure "in order to support various types of propulsion systems, compressors (if applicable), and outer mold lines"
- Pumpdown time is expected to be as long as 30 minutes to reach the minimum pressure rating.
- Thermal control system: none provided in the Hypertube. Tube temperature is expected to vary based on time of day and weather, and competitors will need to design their pods accordingly, mitigating thermal hotspots during pumpdown and test runs.
- Braking system: the only Hypertube-provided braking is the emergency foam pit at the end of the mile-long tube. Pods are expected to provide their own pod-specific braking system, one that will react force to the Hypertube by one of four methods: either against the steel tube, or concrete base, or aluminum subtrack, or central rail. Tube requirements limit friction braking against the subtrack or rail to specified limits.
- Power: none provided on the test track during testing; $240V_{AC}$/50A and $120V_{AC}$/15A power provided in

the pod waiting area up through the pre-launch phase within the tube

- Communications: SpaceX will provide a standard Network Access Panel (NAP) device (approximately 250 mm × 200 mm × 38 mm (10 in × 8 in × 1.5 in)) for mounting on each pod which will communicate to the in-tube network via two, redundant, 1–25 GHz, wave blade antennas. The NAP will also record temperature, acceleration, vibration and shock of each pod in real time during each test run.
- Navigation aids: The tube will include a series of circumferential reflective stripes applied to the inner circumference of the tube, located on the top of the tube, to be used for optical pod navigation, and in particular, awareness of the last 300 meters (1,000 ft) of the tube so pod braking may be safely effected.

Vehicle pods

Three variations of exterior design are currently being explored for vehicle pods. One pod design uses air bearings; this design relies on a system to create a bed of air for the pod to glide upon and is the basis of Elon Musk's original Hyperloop idea.[11] Another pod design uses magnetic levitation; this design was used by the winner of the "Best Overall Design Award" MIT.[30] The third design uses high speed wheels for speeds under 100 mph and air bearings for higher speeds.[31][32] This design was used by University of Colorado, Denver's Hyperlynx team.

The inside design of the pods vary by team. Some of the teams are solely building pods designed for cargo transport. Other teams designed pods to transport passengers, while other designs would allow adjustments to be made to the pod to allow both, while MIT's team's initial design did not have room for a passenger or cargo and solely relied on the engineering of the pod.[33] The University of Colorado, Denver's team incorporated a removable capsule that allows it to be exchanged for a cargo hold or passenger space.[31][32] New York University's team has created a vehicle that only allows cargo transportation.[34]

Competition I: January 2016 and January 2017

Competing teams

Teams advancing to the prototype hardware build stage for 2016 include representatives from four continents and at least six countries. The selected teams include:

- Hyperloop Poland University of Wroclaw and University of Warsaw
- Badgerloop,[1][35][36] University of Wisconsin-Madison[5]
- Bayou Bengals, Louisiana State University[1][6]
- bLoop,[1][37] University of California-Berkeley[5]
- Carnegie Mellon Hyperloop,[1] air-bearing subsystem[38][39] Carnegie-Mellon University[5]
- Codex, pod design uses magnetic levitation suspension; team has only eight members as of February 2016.[40][41][42] Oral Roberts University[5]
- Delft Hyperloop,[1][43][44][45] Delft University of Technology[5]
- Drexel Hyperloop, building a design with air-bearing suspension and a compression braking using built-up air pressure in the Hypertube. Team is approximately 80 undergraduate students.[46][47] Drexel University[5]
- Gatorloop,[1] pod design uses wheel suspension.[48][49] University of Florida[5]
- HyperLift, St. John's School (Texas) The only high school team in the competition.[1]
- Hyperloop UC,[1] pod design has an air-bearing suspension and compressor, just like the 2013 Hyperloop

alpha design.[50][51] University of Cincinnati[5]
- Hyperloop Toronto,[52] University of Toronto[5]
- Hyperloop at Virginia Tech V-17,[1][53] Virginia Tech[5]
- HyperXite, University of California Irvine[1][5]
- Illini Hyperloop,[1] has a history of previous Hyperloop design projects in the Mechanical Science and Engineering program, the first dating to the fall term of 2013. In addition to four subsystem design teams, the Illini group has a fifth, cross-disciplinary team focusing on safety and reliability, the prevention of branching failures.[27] University of Illinois at Urbana-Champaign[6]
- Keio Alpha, Micro-pod architecture consist of active and passive magnetic levitation suspension with a passive eddy current brake. It should weigh less than 45 kg and does not need to carry dummy passenger.[54][55] Keio University[5]
- Lehigh Hyperloop,[1][56][57] Lehigh University[5]
- Hyperloop Makers UPV team Valencia, Spain, magnetic levitation based on attraction to the top of the tube. Rail-free and clean tube layout, compensation of inertial forces, reduced air-evacuation cost and up to 30% savings in infrastructure. Powered by detachable batteries, propulsion through compression and expansion of air with a nozzle. Universitat Politècnica de Valencia.[58][59]
- Mercury Three, University of Wisconsin, Milwaukee[1][6]
- MIT Hyperloop Team,[1] magnetic levitation suspension and high speed are the design focal points. no compressor for this test pod.[60] Massachusetts Institute of Technology[5]
- NYU Hyperloop, *Slate*, a freight-only pod, will use air-bearing suspension; is being designed and built by a team of, as of February 2016, less than ten undergraduate students.[34][61] New York University[6]
- OpenLoop,[1][62][63] pod design will use an air-bearing suspension and compressor similar to the original 2013 Hyperloop alpha design.[64][65] multi-university team of Cornell University (suspension), Harvey Mudd College (control systems), University of Michigan (fuselage), Northeastern University (suspension), Memorial University of Newfoundland (compressed air), and Princeton University (electrical and cooling)[6]
- Purdue Hyperloop,[1][66][67] Purdue University[5]
- rLoop, Inc.,[1][68] The only non-student team that advanced in the competition and won the "Innovation Award."[5][69][70] Initially conceived on a Reddit forum, rLoop is now a full-fledged, funded Hyperloop initiative with activity in over 14 countries.[71][72]
- TAMU Aerospace Hyperloop,[73] Texas A&M[5]
- Team Frigates,[74] Shiv Nadar University, Undergraduate design team consisting of 8 students from different disciplines, namely Mechanical, Physics and Electronics and Communications.
- Team HyperLynx,[1] pod design uses high-speed wheel suspension, with a modular/removable payload design for a pod with a total mass of 140 kilograms (300 lb), aiming for a top speed of 400 kilometers per hour (250 mph).[31][32] University of Colorado-Denver[5]
- UCSB Hyperloop, pod design will use magnetic levitation suspension. Test runs will be accelerated by the Hypertube pusher. Undergraduate design team (senior project) of 20 members.[75] University of California-Santa Barbara[5]
- UMD Loop,[1][76] University of Maryland[5]
- USC Hyperloop, University of Southern California[6]
- UWashington Hyperloop, University of Washington[1][5]
- Waterloop,[77] a Canadian team designing a pod with air levitation, magnetic brakes and control, targeted at 250 kg (550 lb) aiming for a cruising velocity of 120 m/s (430 km/h) while carrying a payload of 4,000 kg (8,800 lb).[78] University of Waterloo[5]

- VicHyper,[1][79] Royal Melbourne Institute of Technology[6]
- WARR Hyperloop,[1] pod design will use an electrodynamic suspension system to levitate and an axial compressor to minimize aerodynamic drag from the residual air inside the tube when the pod is moving at high velocity.[80][81] Technical University of Munich[5]
- HyperPodX,[82] a German team with a pod designed to levitate using a series of fixed magnets following a Halbach array and a pusher with 4 electric motors for acceleration to high velocities[83] The team is comprised from the conjoined effort from Engineering Physics students from the University of Oldenburg and the Hochschule Emden/Leer(de)[5]

Phase 1: Design weekend (January 2016)

Five design awards were assigned following the January design weekend.[5]

MIT Hyperloop Team's design was awarded received the "Best Overall Design Award",[5] among the 23 designs selected to move to the prototype stage. The design proposes a 250 kg (551 lb) pod with a carbon fiber and polycarbonate sheet exterior. It is elevated by a passive magnetic levitation system comprising 20 neodymium magnets that will maintain a 15 mm (0.6 in) distance above the track.[30] The team says with air pressure at 140 Pascals, the pod could accelerate at 2.4 G and have 2 Newton aerodynamic drag when traveling at 110 m/s. The design includes a fail-safe braking system that automatically halts the pod should the actuators or computers fail, and low speed emergency drive wheels that can move the pod 1 m/s.[30]

Delft Hyperloop received a "Pod Innovation Award",[5] while *Badgerloop*, *Hyperloop at Virginia Tech*, and *HyperXite* at UC Irvine each received a "Pod Technical Excellence Award". One award for "Best Non-Student Team" was awarded to *rLoop*, a team which formed on the SpaceX subreddit.[5]

In addition to the five pod awards above, nine subsystem awards and three "design only" awards were given to teams, most to teams that were not chosen to continue on to the on-track competition. Technical awards for outstanding technical merit in subsystem and design, based on "innovation and uniqueness of subsystem design, full Hyperloop system applicability and economics; level of design detail; strength of supporting analysis and tests; and quality of documentation and presentation." [84]

Best Overall Subsystem Award: Auburn University Hyperloop Team, Auburn University;[85][86] Special Innovation Award in the Other Subsystem: RIT Imaging, Rochester Institute of Technology; :Levitation Subsystem Technical Excellence Award: TAMU Aerospace Hyperloop, Texas A&M; Braking Subsystem Technical Excellence Award: VicHyper, RMIT University; Propulsion/Compression Subsystem Technical Excellence Award: Makers UPV Team (http://hyperloopupv.com/), Universitat Politècnica de València; Safety Subsystem Technical Excellence Award: UWashington Hyperloop, University of Washington (linked above); Subsystem Technical Excellence Awards: Hyped,[87] University of Edinburgh; Conant Hyperloop Club, Conant High School;[88] Subsystem Innovation Award: Ryerson's International Hyperloop Team, Ryerson University.[84] Top Design Concept Award: Makers UPV Team (http://hyperloopupv.com/) (see above); Design Concept Innovation Award: Nova Hyperloop Team, University of Cairo; Design Concept Innovation Award: Auburn University Hyperloop Team (see above).[84]

Phase 2: Test track runs (January 2017)

Phase 2 of the competition ran 27–29 January 2017[1][89][90][91][2] after previously being planned for as early as August 2016.[92] 27 teams competed in two overall categories and five subcategories. Each pod in the competition needed to progress through ten sequential tests, only the last of which would be a vacuum-environment speed run in the mile-long Hypertube. Problems with dust and misalignment of the track limited performance and caused widespread problems.[93] Just three of the competition pods successfully completed the nine tests that enabled them to make a vacuumized tube run on 29 January. The winning teams were:[94][95][96][97]

Overall

- Fastest Pod Award: WARR Hyperloop (Technical University of Munich)
- Overall Score: Delft Hyperloop (Delft University of Technology)

Subcategory awards

- Best Performance in Flight: WARR Hyperloop (Technical University of Munich)
- Best Performance in Operations: UMDloop (University of Maryland, College Park)
- Design and Construction: Delft Hyperloop (Delft University of Technology)
- Pod Innovation Award: Badgerloop (University of Wisconsin–Madison) and rLoop (Reddit)
- Safety and Reliability: MIT Hyperloop (Massachusetts Institute of Technology)

Competition II (August 2017)

The SpaceX "Hyperloop Pod Competition II" was held on 25–27 August 2017.[3] The rules for Competition II were released in August 2016. Unlike Competition I — where multiple judging criteria were used and multiple classes of vehicles and vehicle subsystems were judged — Competition II will be judged by only a single criterion: "maximum speed with successful deceleration (i.e. without crashing)."[98][99]

While approximately 24 teams competed, only the top three were selected to make test runs in the mile-long *Hypertube* test track. *WARR Hyperloop* won the competition with a test run clocked at 323 kilometres per hour (201 mph). *Paradigm Hyperloop* won second and *Swissloop* placed third.[3]

The 24 selected teams participating in this second competition as of April 2017 were the following:[100]

Team Name	**University**	**Team website** (not references for any statements)
512 Hyperloop	University of Texas at Austin	512 Hyperloop (https://www.512hyperloop.com/)
AZLoop	Arizona State University;[101] Embry-Riddle Aeronautical University; Northern Arizona University; Thunderbird School of Global Management	Arizona Hyperloop (http://www.azhyperloop.com/)
Badgerloop	University of Wisconsin-Madison	Badgerloop (https://badgerloop.com/)
Binghamton Hyperloop	Binghamton University	Binghamton Hyperloop (http://binghamtonhyperloop.com/)
		Team Diggerloop (http://ams

DiggerLoop	Colorado School of Mines[102]	.mines.edu/MECH-Home)
Hornet Hyperloop	California State University, Sacramento	Team Hornet (https://www.hornethyperloop.com/)
HYPED	University of Edinburgh	HYPED website (https://hyp-ed.com/)
Hyper Poland University Team	Warsaw University of Technology	Team Poland (http://www.hyperpoland.com/)
Hyperloop India	BITS Pilani[103]	Team BITS (http://hyperloopindia.in/)
HyperPodX	University of Applied Sciences Emden-Leer; University of Oldenburg	HyperPodX (http://hyperpodx.com/)
HyperXite	University of California, Irvine	Team UC (http://www.hyperxite.com/)
Illini Hyperloop	University of Illinois at Urbana Champaign	
Keio Alpha	Keio University	Team Keio (http://keioalpha.wixsite.com/hyperloop)
Michigan Hyperloop	University of Michigan, Ann Arbor	Team Michigan (https://www.michiganhyperloop.com/)
Paradigm	Northeastern University, Memorial University of Newfoundland	Team Paradigm (http://paradigm.earth/)
Purdue and UPV Atlantic Hyperloop Design Team	Purdue University (Purdue Hyperloop); Universitat Politecnica de Valencia (Hyperloop UPV)	Purdue (http://www.hyperloopupv.com/) Team UPV (http://www.purdue.edu/hyperloop/)
Swissloop	ETH Zurich	Team Swissloop (http://www.swissloop.ch)
Texas Guadaloop	University of Texas at Austin	Team Guadaloop (https://www.guadaloop.com/)
UCSB Hyperloop II	University of California, Santa Barbara	Team UCSB (http://www.ucsbhyperloop.com/)
UMD Loop	University of Maryland	Team Maryland (http://www.umdloop.com/)
University of Washington	University of Washington	Team UW (http://hyperloop.io/)
Hyperloop at Virginia Tech	Virginia Tech	Team VTech (http://www.vthyperloop.com/)
WARR Hyperloop	Technical University of Munich	Team WARR (http://hyperloop.warr.de/)
Waterloop	University of Waterloo	Waterloop (https://teamwaterloop.ca/)

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